Performance of Heat Pipes under Different Inclinations and Working Fluids

Yogesh Ramdas Mahulkar, C. M. Sedani

Abstract: ***For various applications of heat pipes are widely used according to heat conductivity capacity of working fluid. Based on the heat pipe capacity, heat pipes used in cooling electronic industry for controlling temperature of electronic parts. Some applications need to apply heat pipes at various inclinations for cooling purpose. So need to study heat pipes at various inclinations for best results in working condition. Here we study different heat pipes at various inclinations using different working fluids for heat pipe. Among various fluids, methanol as working fluid establishes best result at high and low inclination. The configuration of evaporator section heated with hot water provided inside evaporator jacket and condenser section cooled with liquid at atmospheric passed inside condenser jacket.***

Keyword: heat pipe, working fluid, inclination, screen mesh, phosphorus bronze.

I. INTRODUCTION

Amir Faghri [1] identified the types of the heat pipe with the application for better understanding the operation and principal of heat pipes. The explanation of the vapor and liquid distributions provide better understanding of the transport phenomenon. Heat pipe analysis and simulation done with the various types of the heat pipe with thermal-fluid phenomenon occurring within a heat pipe. The explanation was done on the numerical analysis and experimentation on the various types of heat pipe with the steady state, transient and frozen start up. M. N. Khan, Sandeep Pathak, etl [2] discussed the working and limitation of heat pipe. The capillary limitation has required overcoming the all pressure losses inside the heat pipe. Viscous limitation deals with the total vapor pressure developed in vapor flow inside the heat pipe. The sonic limitation occurred during start up or at low temperature operation with the increased vapor velocity, inertial or dynamic, pressure effects which results in the temperature gradient along the heat pipe. The entrainment limitation can be expressed in the Weber number as this limit due to counter flow of the vapor and liquid flow in the heat pipe. The boiling limitation based on the circumferential heat flux with formation of the bubble and collapse of the bubbles. Wick structure of the reducing the radius will cause for a very large amount of pressure loss and the thicker wick reducing n the wick superheat. Effect of the fluid charge shows the optimum performance of the heat pipe was achieved with the 50 – 75 % of filling ratio at 50^{o} inclination angle.

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Effect of working fluid is depends on the properties of the working fluid compatible with case and wick material. Nano-fluids give better result than the conventional with improve in the thermal characteristics of the heat pipe. Effect of tilt angle on the performance of heat pipe affects with changing thermal characteristics with gravity changes. When the evaporator is below the condenser, performance of heat pipe increase with increasing tilt angle as it increases the rate of liquid flow from condenser to evaporator. A. K. Mozumder1, A. F. Akon1, M. S. H. Chowdhury1 and S. C. Banik, [3] demonstrate the operation of heat pipe with plotting the graph of axial temperature distributions, thermal resistances and overall heat transfer coefficient for the different heat input, different filling ratio, different working fluids. The axial temperature distributions for different fluids show that the slopes are lower than water and methanol at different heat inputs. Also the thermal resistance for different fluid ratio at different heat inputs with acetone working fluid show minimum value. The overall heat transfer coefficient at different heat inputs with acetone working fluid show maximum value. When acetone used as working fluid, the results show minimum values of temperature difference across evaporator and condenser with different filling ratios.

Xue Zhihu, Qu Wei [4] demonstrated the analysis of start up and effects of inclination angle on performance of pulsating heat pipe. For startup analysis the results of the different working fluids are plotted with saturation pressure against temperature for ammonia, acetone, water, R134 and HFO-123yf. Among different working fluids, the ammonia gives good performance and less time for start up. Also in the horizontal condition and nucleation boiling gives better performance of ammonia than other fluids. In analysis of effect of inclination angle, the ammonia with half filling ratio at different angles and at different heat inputs, the occurrence of oscillation, frequency of change the bulk circulation and liquid slugs phenomenon observed with ammonia as working fluid. The increases the chances of burnout at low filling ratio and increases the thermal resistance. At same filling ratio and increase in the input heat load, decreases the thermal resistance with increase in the inclination angles. Per Wallin [5] attentive on the selection of working fluid, describe various operation limits, compatibility with wick and case materials. Sonic limit, boiling limit, entrainment limit and capillary limit results with working fluids acetone, methanol and water for copper case material show water provide best results. Maziar Aghvami, Amir Faghri [6] analyzed the flat heat pipe with various heating and cooling configuration like single and multiple heat sources and sinks. The effects of different thermal conductivities, heat inputs, and heat source size observed for vapor

velocity, capillary pressure, vapor temperature and wall temperature. The effect of increase thermal conductivity and heat input results in decrease in wall temperature. The effect of heat source size results in increase in wall temperature. The vapor pressure decrease and vapor velocity increase with increase in heat input in evaporation section and vice versa in condenser section. R. Senthilkumar, S. Vaidyanathan and B. Sivaraman [7] investigation of performance of heat pipe with aqueous solution of n pentanol. In variation of heat pipe thermal efficiency, the maximum increase in thermal efficiency with increase in inclination of heat pipe upto 30^0 tilt angle with favorable effects of gravitational force and heat transport. It observed the higher value of thermal efficiency of when used as working fluid in heat pipe at various heat inputs. In effect of thermal resistance, aqueous solution of n-pentanol has less thermal resistance than water at various heat input and decrease in thermal resistance of aqueous solution of n-pentanol than water with increase in heat input and inclination due to low surface temperature and high heat transport. The high value of overall heat transfer coefficient observed with aqueous solution of n-pentanol than water at high inclination is due to high heat transport capacity. The effects of temperature distribution in evaporator at various heat inputs and inclination observed high value at 0^0 tilt angle due to improper mixing of vapor and the condensate. MOHAMED S. EL-GENK and LIANMIN HUANG [8] investigation of transient response of a water heat pipe with steady state energy balance, transient results, heat-up and cool-down time constants, effect of cooling water flow rate on time constants and effect of electric power input on time constants.

II. EXPERIMENTAL RESULTS

The study of various configuration of heat pipes as different cooling methods of the condenser section and different heating methods of evaporator sections going on for better results. Here the condenser section is cooled with water at ambient temperature passed inside the water jacket of condenser section and evaporator section is heated with hot water passed inside the water jacket of evaporator section. As shown in figure 1, heat pipes are used with different working fluid for experimentation purpose.

Fig. 1 Heat pipe configuration of heating and cooling section.

The design of the heat pipe jackets are such that the inside area of jacket on evaporator section and inside area of jacket on condenser section is same. For experiment purpose, same flow rate of cold water over condenser section and hot water over evaporator section is maintained. The adiabatic section is used as 10% of the total length and remaining length is equally distributed in evaporator section and condenser section. The heat pipe shape is annular with copper material used for manufacturing pipe. The wick material used is phosphorus bronze and wick structure used for heat pipe is wrapped screen with single layer of wick with 180 wire mesh. The diameter of heat pipe is 12 mm and evaporator section is directly below the condenser section at 90° inclination. The design of each pipe same as above, only the working fluid is

different such as water, acetone, ethanol and methanol.

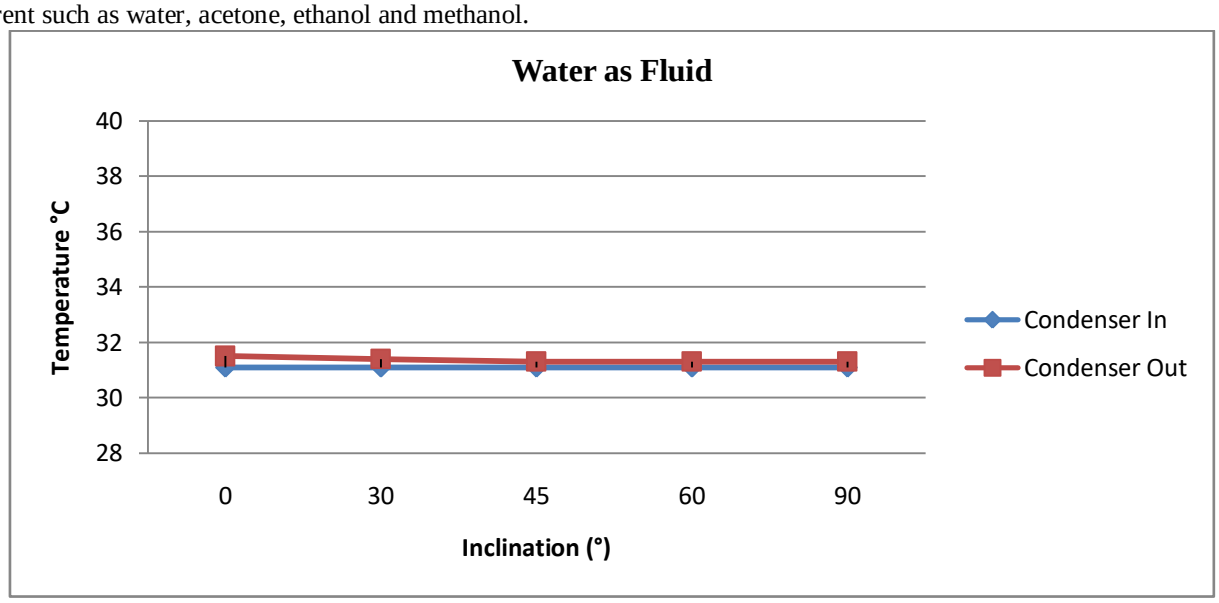

Fig. 2a) Heat pipe using water as working fluid at different inclination

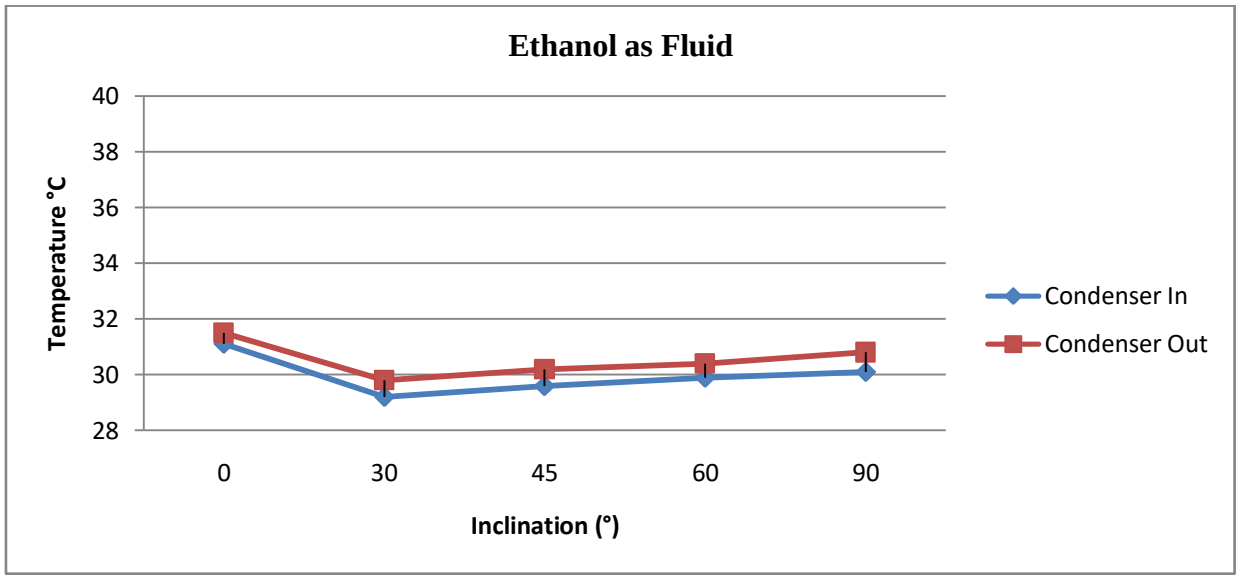

Fig. 2b) Heat pipe using Ethanol as working fluid at different inclination.

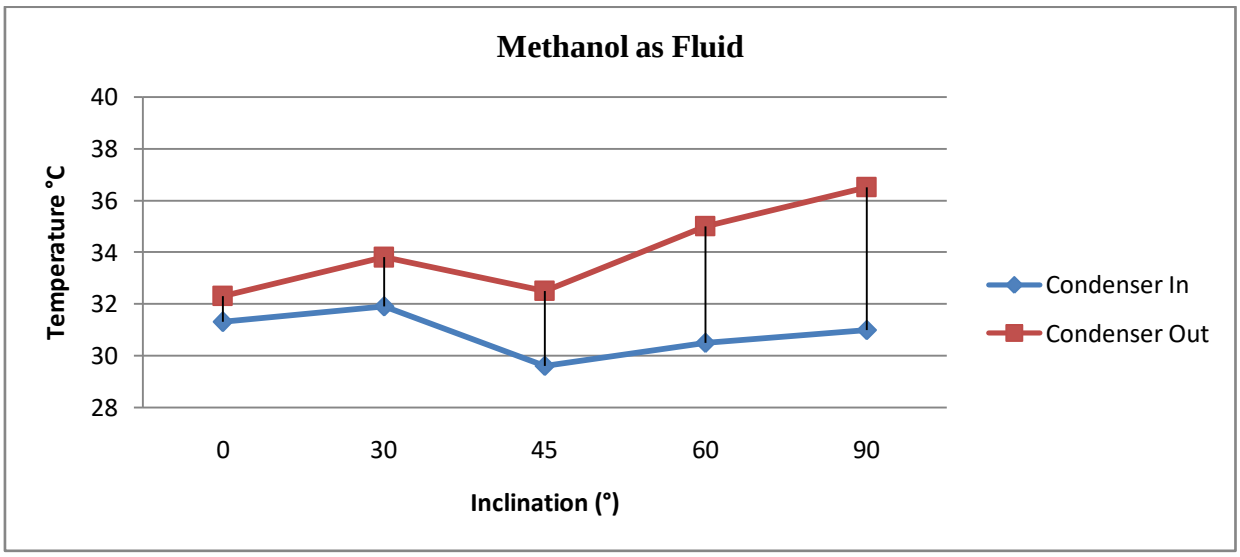

Fig. 2c) Heat pipe using Methanol as working fluid at different inclination.

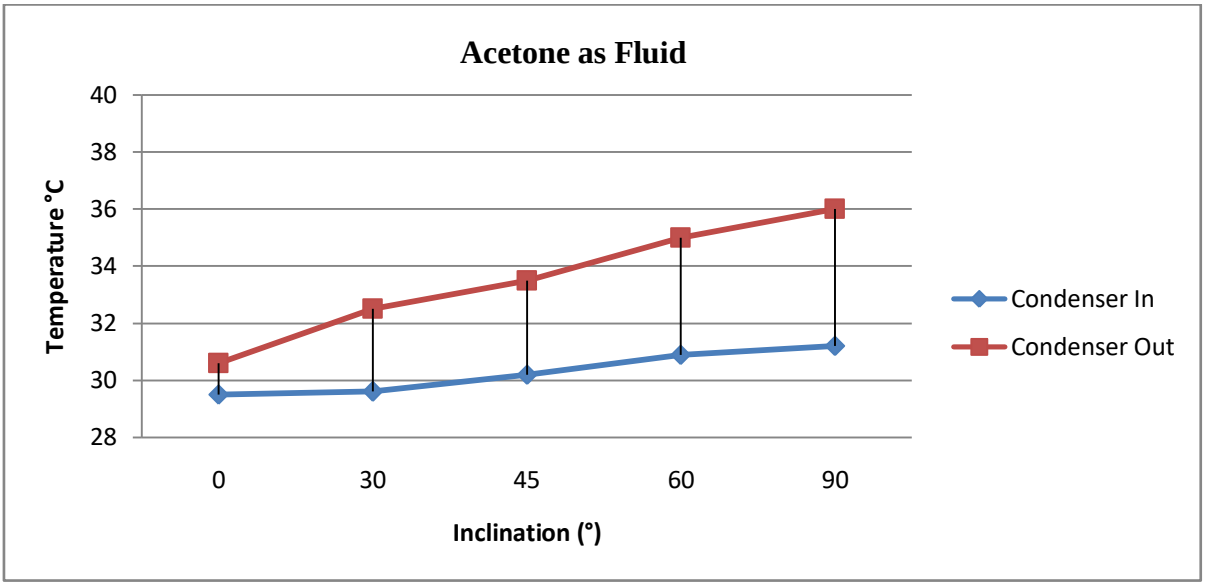

Fig. 2d) Heat pipe using Acetone as working fluid at different inclination.

The different charts indicate condenser inlet temperature and condenser outlet temperature at various inclinations for different working fluid in heat pipe. The difference between condenser inlet temperature and condenser outlet temperature at particular inclination should be more for better result. Water using working fluid not showed remarkable difference between the temperatures as comparatively Methanol using working fluid in heat pipe. Most of the heat pipes showed maximum result at 90° of inclination of heat pipe using different fluids and Methanol fluid shows secure results at different inclination.

III. CONCLUSION

From the experimentation of heat pipes under different working fluid at single layer of wrapped screen wick structure, it observed that methanol provide better results than the other working fluids. The observations are as water using as working fluid the best result achieved at 0° inclination and among other working fluids methanol provide best results at from 0° to 90°. Ethanol, Acetone and Methanol are providing best result at 90° inclination of heat pipe.

REFERENCES

1. Amir Faghri, Review and Advances in Heat Pipe Science and Technology, Journal of Heat Transfer, ASME DECEMBER 2012, Vol. 134 / 123001-1.
2. M. N. Khan, Sandeep Pathak, Parametric study of the performance of heat pipe- a review, International Journal of Mechanical Engineering and Technology (IJMET), volume 4, Issue 1, January-February (2013), pp. 173-184.
3. K. Mozumder1, A. F. Akon1, M. S. H. Chowdhury1 and S. C. Banik, PERFORMANCE OF HEAT PIPE FOR DIFFERENT WORKING FLUIDS AND FILL RATIOS, Journal of Mechanical Engineering, Vol. ME 41, No. 2, December 2010.
4. Xue Zhihu, Qu Wei, Experimental study on effect of inclination angles to ammonia pulsating heat pipe, Chinese Journal of Aeronautics, (2014), 27(5): 1122–1127.
5. Per Wallin, Heat Pipe, selection of working fluid, Project Report MVK160 Heat and Mass Transfer May 7, 2012, Lund, Sweden.
6. Maziar Aghvami, Amir Faghri, Analysis of flat heat pipes with various heating and cooling configurations, Applied Thermal Engineering 31 (2011) 2645e2655.
7. R. Senthilkumar, S. Vaidyanathan and B. Sivaraman, Performance investigation of heat pipe using aqueous solution of n-Pentanol with different inclinations, Journal of Mechanical Science and Technology 25 (4) (2011) 923~929 DOI 10.1007/s12206-011-0207-4.
8. MOHAMED S. EL-GENK and LIANMIN HUANG, An experimental investigation of the transient response of a water heat pipe, Int J. Heat Mass Transfer. Vol.3 6, No. 15.&q 3823-3830,1993.